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Ladybeetles (Coccinellidae) Chapter 8.4

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Abstract

The majority of Coccinellidae are beneficial predators and they have received considerable research attention because of their potential as biological control agents. Indeed the role of coccinellids as predators of pest insects has been a major factor in the movement of coccinellids between countries. The commercial production of coccinellids by biological control companies and local producers led to a rapid increase in distribution thoughout the 1990's. To date, 13 alien coccinellid species have been documented in Europe; 11 of these are alien to Europe (two are alien to Great Britain and Sweden but native within Europe). The distribution of alien coccinellids in Europe mirrors the biogeographical distribution and patterns of introduction. Some species have dispersed widely; *Harmonia axyridis* has spread rapidly from countries where it was deliberately introduced to many others across Europe. The ecological and economic impacts of alien coccinellids are not well documented. In this chapter we provide an overview of the temporal and spatial patterns of alien coccinellids in Europe.

Keywords

Coccinellid, ladybird, alien, Europe, biological control agent, *Harmonia axyridis*, distribution patterns

8.4.1 Introduction

The Coccinellidae are commonly referred to as ladybirds (Britain, Australia, South Africa), ladybugs (North America) or ladybeetles (various countries). Coccinellids have received considerable research attention because of their role as predators of pest

insects. The Coccinellidae comprises over 4200 species worldwide (Iperti 1999, Majerus et al. (2006a)). Audisio and Canepari 2009 report that there are approximately 253 species and subspecies of Coccinellid in Europe. However, a review in 1999 documented only 110 species including species acclimatized through the 1900s: *Rodolia cardinalis*, *Cryptolaemus montrouzieri*, *Rhyzobius (Lindorus) lophanthae*, *Rhyzobius forestieri* and *Serangium parcestosum* (Iperti 1999). The discrepancy in species number from these different sources can not solely be accounted for by the addition of new species arriving in Europe but is an indication of the dynamic state of coccinellid taxonomy and the difficulty of establishing a checklist for Europe. Not only is the taxonomy of coccinellids under review but also the arrival of new species is ongoing; recently the UK Ladybird Survey (www.ladybird-survey.org) reported the first British record of *Cynegetis impunctata* (Thomas et al. 2009). There is also considerable variation in reported coccinellid diversity between countries. Great Britain is relatively species poor with only 46 species (Majerus et al. 2006b) whereas in contrast the Netherlands have 86 native coccinellid species. The proportion of alien species for this group is quite high in Europe, with 13 species observed in the wild to date. Two of these are native to Europe but alien within Great Britain (*Henosepilachna argus*, *Scymnus impexus*) and Sweden (*Scymnus impexus*). For the remainder of this section only the 11 species alien *to* Europe (and not the three alien species *in* Europe) will be considered.

The majority of coccinellid species (about 90 %) are beneficial predators (others are phytophagous or mycophagous); consequently coccinellids have played a significant role in the development of biological control strategies (Berthiaume et al. 2007, Brown and Miller 1998, Galecka 1991, Gurney and Hussey 1970, Iperti 1999, Obrycki and Kring 1998). This has been a major factor in the movement of coccinellids between countries worldwide.

8.4.2 Taxonomy of the coccinellid species alien to Europe

The family Coccinellidae belongs to the coleopteran superfamily Cucujoidea and is a member of the phylogenetic branch of Coleoptera termed the Cerylonid complex of families (Cerylonidae, Discolomidae, Alexiidae, Corylophidae, Endomychidae and Lathridiidae). Worldwide there are six subfamilies of Coccinellidae: Sticholotidinae, Chilocorinae, Scymninae, Coccidulinae, Coccinellinae and Epilachninae although a recent phylogeny suggests a seventh subfamily, Ortaliinae (Fürsch 1990, Kovář 1996). European species are mainly represented by three subfamilies: Scyminae, Chilocorinae and Coccinellinae. There are very few European Sticholotinae, very few Coccidulinae and only three species of Epilachninae (Iperti 1999). Although the species list for Coccinellidae in Fauna Europaea (Audisio and Canepari 2009) includes representatives from all six subfamilies.

Species alien *to* Europe are quite evenly represented between five of the six subfamilies. Three species are observed in the subfamily Coccidulinae (two Coccidulini

and one Noviini) and in the Scymninae (two Scymnini and one Hyperaspidini). Two species are in the Chilocorinae (two Chilocorini) and Coccinellinae (two Coccinellini). One species is in the Sticholotidinae (Sticholotidini). There are no Epilachninae that are alien to Europe (although *Henosepilachna argus* is alien *in* Europe).

Most species in the Epilachninae are phytophagous, while the majority of species in the other subfamilies are predatory. The preferred diets of the two feeding stages in the life-cycle, the larval and adult stages, are generally the same. Most predatory ladybirds feed on either aphids or coccids (a few feed on both), however some predatory species feed on mites, adelgids, aleyrodids, ants, chrysomelid larvae, cicadellids, pentatomids, phylloxera, mycophagous coccinellids and psyllids (Dixon 2000). Indeed, a small number of species within the Coccinellinae and Epilachninae are mycophagous, feeding on the hyphae and spores of fungi. There is also considerable variability in the degree of dietary specialisation between species (Hodek 1996). Some species have a very narrow preferred prey range, such as a single species of mite, aphids of a single genus, or plants of a single family, other species have a wide prey range. *Harmonia axyridis*, for example, will feed on aphids, coccids, adelgids, psyllids, and the eggs and larvae of many other insects, including other coccinellids and lepidopterans (Legaspi et al. 2008, Ware and Majerus 2008). Ladybirds exhibit complex adaptations to specific or more general diets such as mandibular dentition, gut length and structure, and morphological features that affect mobility (Hodek 1996). Many predatory coccinellids will feed on alternative foods, such as pollen, nectar, honey-dew and fungi (many also resort to cannibalism) when preferred prey are scarce (De Clercq et al. 2005, Hodek 1996).

Coccinellids are distinguished from the remainder of the Cerylonid complex of families by a number of adult characteristics: five pairs of abdominal spiracles, tentorial bridge is absent, anterior tentorial branches are separated, frontoclypeal suture absent, apical segment of maxillary palpus never aciculate, galea and lacinia separated, mandible with reduced mola, front coxal cavities open posteriorly, middle coxal cavities open outwardly, metaepimeron parallel-sided, femoral lines present on abdominal sternite 2, tarsal formula 4-4-4 or 3-3-3, tarsal segment 2 usually strongly dilated below (Kovář 1996). In Europe, the diagnostic features of the family Coccinellidae can be considered in more simple terms (Majerus 2004). They are small to medium sized beetles (1.3–10 mm in length). There body shape is oval, oblong oval or hemispherical (upper surface convex and lower surface flat). They have large, compound eyes. The antennae are often 11-segmented but this figure varies and can be as low as seven. The mouthparts consist of large, strong mandibles; four-segmented maxillary palps (terminal segment axe shaped) behind the mandibles; labium divided into the pre-labium and post-labium; three-segmented labial palps; and the labrum. The head can be partly withdrawn under the pronotum. The pronotum is broader than long and has anterior extensions at the margin. The legs are short and can be retracted into depressions under the body. The tarsi are usually four segmented but the third segment is small and hidden in the end of the second segment. Each tarsus bears two claws. The abdomen has ten segments (Kovář 1996, Majerus et al. 2006a).

8.4.3 Temporal trends of introduction in Europe of alien coccinellids

The first species of coccinellid to be introduced into Europe was the vedalia beetle, *R. cardinalis,* for the control of the cottony cushion scale (coccid), *Icerya purchasi* (Figure 8.4.1). Two further species were introduced during the early twentieth century (mainly to the Mediterranean regions including France, Portugal and Italy) but there then followed a period of stagnation and respect to biological control in general. This correlates with the trend towards chemical insect pest control with the development of synthetic pesticides. From the 1980's onwards there were a considerable number of introductions on an extensive scale across Europe through the use of tropical coccinellids to control glasshouse pest insects.

8.4.4 Biogeography of the coccinellid species alien *to* Europe

Each continent has a specific fauna of coccinellidae. Belicek (1976) stated that "many species develop their cycles in life zones delineated by the general physiography of the continents (mountainous barriers) and climatic patterns combined with the types of vegetation in a given zone". Glaciation had profound effects on the distribution of coccinellids and the level of endemism is further controlled by ecological factors including temperature, food and natural enemies.

The temperate zones of Europe and North America are heavily infested by Aphidae and grasslands in these regions contain coccinellids from the tribus Coccinellini (*Coccinella* spp., *Adalia* spp., *Harmonia* spp.) and Hippodamiini, Cheilomenini and Scymnini. Open deciduous and coniferous forests in this temperate zone contain other genera of Coccinellini (*Anatis* spp., *Myrrha* spp., *Myzia* spp.). Tropical zones in central and South Africa, South America, India and China where Coccidae are abundant are characterised by coccinellids from the tribus Chilocorini (*Chilocorus* spp., *Exochomus* spp., *Brumus* spp.), Scymnini, Hyperaspini, Coccidulini and Noviini. In the Mediterranean regions of Europe, aphids and coccids are found together and are attacked by coccinellids from the temperate and tropical zones (Iperti 1999).

It is interesting to note that coccinellids native to temperate zones enter either simple quiescence or intense diapause as adults. In contrast, exotic species such as *Rhyzobius lophanthae* and *Cryptolaemus montrouzieri* do not enter quiescence or diapause but instead resist drastic changes in climate by reducing the speed of development during winter but not entirely stopping it (Iperti 1999).

The early introductions of alien coccinellids were characteristically as classical biological control agents; the predatory coccinellid originated from the same country as the target pest insect. So, for example, both *R. cardinalis* and *I. purchasi* originated from Australia; *R. lophanate* and various Diaspididae (*Pseudolacaspis pentagona*, *Quadraspidiotus perniciosus*, *Chrysomphalus dictyospermi*, *Parlatoria blanchardi*) from Australia and New Zealand; *C. montrouzieri* and *Planococcus citri* from Australia. Notably all these species are from tropical regions and were introduced into Mediterranean regions for

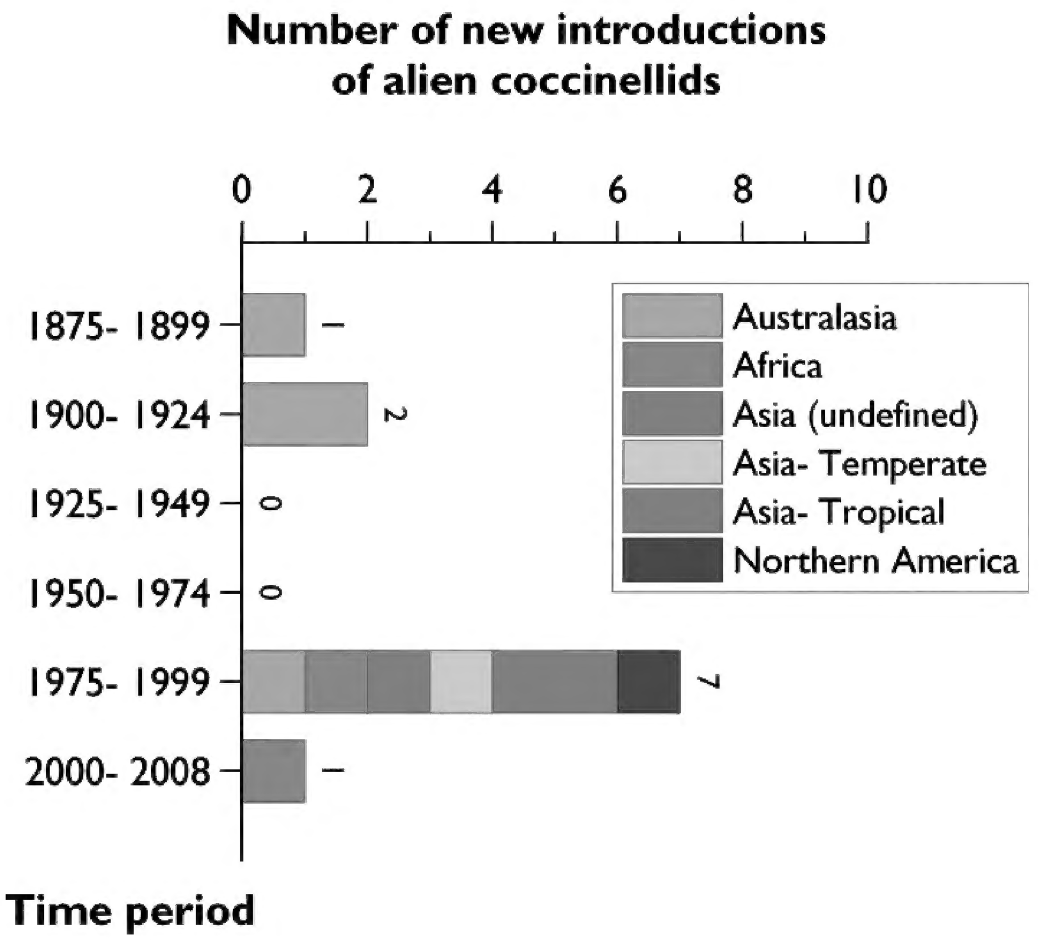

Figure 8.4.1. Temporal trends in the mean number of new records per year of coccinellid species alien *to* Europe from 1875 to 2008. The number above the bar indicates the total number of alien species newly recorded during the considered time period.

control purposes (Figures 8.4.1 and 8.4.2). In contrast, the coccinellid species selected to reinforce the activity of native natural enemies in temperate regions of Europe are from temperate regions of the globe for example, temperate Asia (*H. axyridis*) or North America (*Hippodamia convergens*).

8.4.5 Distribution of alien Coccinellids in Europe

The distribution of alien coccinellids in Europe mirrors the biogeographical distribution and patterns of introduction (Figure 8.4.3). Some species have dispersed widely; *H. axyridis* has spread rapidly from countries where it was deliberately introduced to many others across Europe. Furthermore, the commercial production of coccinellids by biological control companies and local producers led to a rapid increase in distribution thoughout the 1990's.

8.4.6 Use of alien coccinellids for biological control in Europe

The ecosystem service that predatory coccinellids provide in consuming pest insects has been recognised for over a century. The vedalia ladybird, *R. cardinalis*, is considered to have initiated modern biological pest control. It was released as a classical bio-

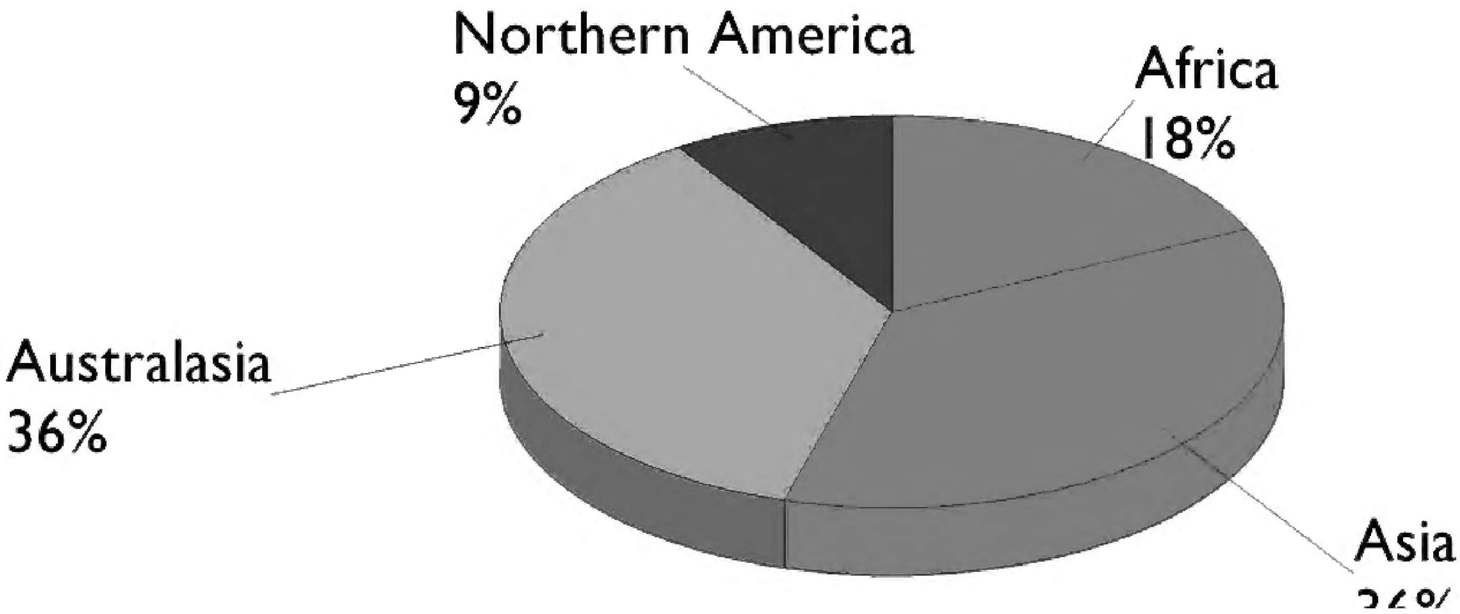

Figure 8.4.2. Origin of the 11 alien coccinellid species established in Europe.

logical control agent (native to Australia) in 1887 to control an alien cottony cushion scale (coccid), *I. purchasi*, which was threatening the citrus industry of California. The vedalia ladybird and the cottony cushion scale are still present in Californian citrus groves but the ecological balance between predator and prey ensures that the pest is no longer a problem (Caltagirone 1989, Majerus et al. 2006a).

The successful introduction of *R. cardinalis* for the control of *I. purchasi* resulted in considerable focus on Coccinellidae for importation programmes worldwide (Obrycki and Kring 1998). Over 40 species of coccinellid were introduced to North America following *R. cardinalis* during a period colloquially referred to as the "ladybird fantasy" (Caltagirone 1989, Dixon 2000). This worldwide phenomenon was mainly ineffectual; only four of over 40 species introduced to North America during this time established (Caltagirone 1989). In recent times there have been 155 attempts to control aphids and 613 to control coccids worldwide through the introduction of ladybirds (Dixon 2000). On a scale of success (complete, substantial, partial or no control) only one attempt to control aphids using coccinellids has been ranked as substantially successful and none have been completely successful (Dixon 2000). In contrast, 23 complete and 30 substantial successes have been achieved against coccids (Dixon 2000). In a few cases the introduced coccinellid species has had far-reaching, unacceptable impacts on biodiversity and so has been deemed an invasive species. *Harmonia axyridis*, harlequin ladybird, is the only such example in Europe (Brown et al. 2008a).

All of the 11 alien coccinellids in Europe have been intentionally released as biological control agents of pest insects. The first coccinellid to be introduced to Europe was *R. cardinalis* as a predator of *I. purchasi* in 1888 (Portugal), 1901 (Italy) and 1912 (Italy and France). This species was subsequently released through the mid and late 1900s to Italy, Portugal, Israel, France, Spain, Malta, Great Britain, Albania, Cyprus, Switzerland and the Ukraine. *Cryptolaemus montrouzieri*, native to Australia, was intentionally released to control mealybugs (Pseudococcidae), *Planococcus citri*, from 1908 in Italy. Subsequent releases were made in Spain (1926), Corsica (1970), France

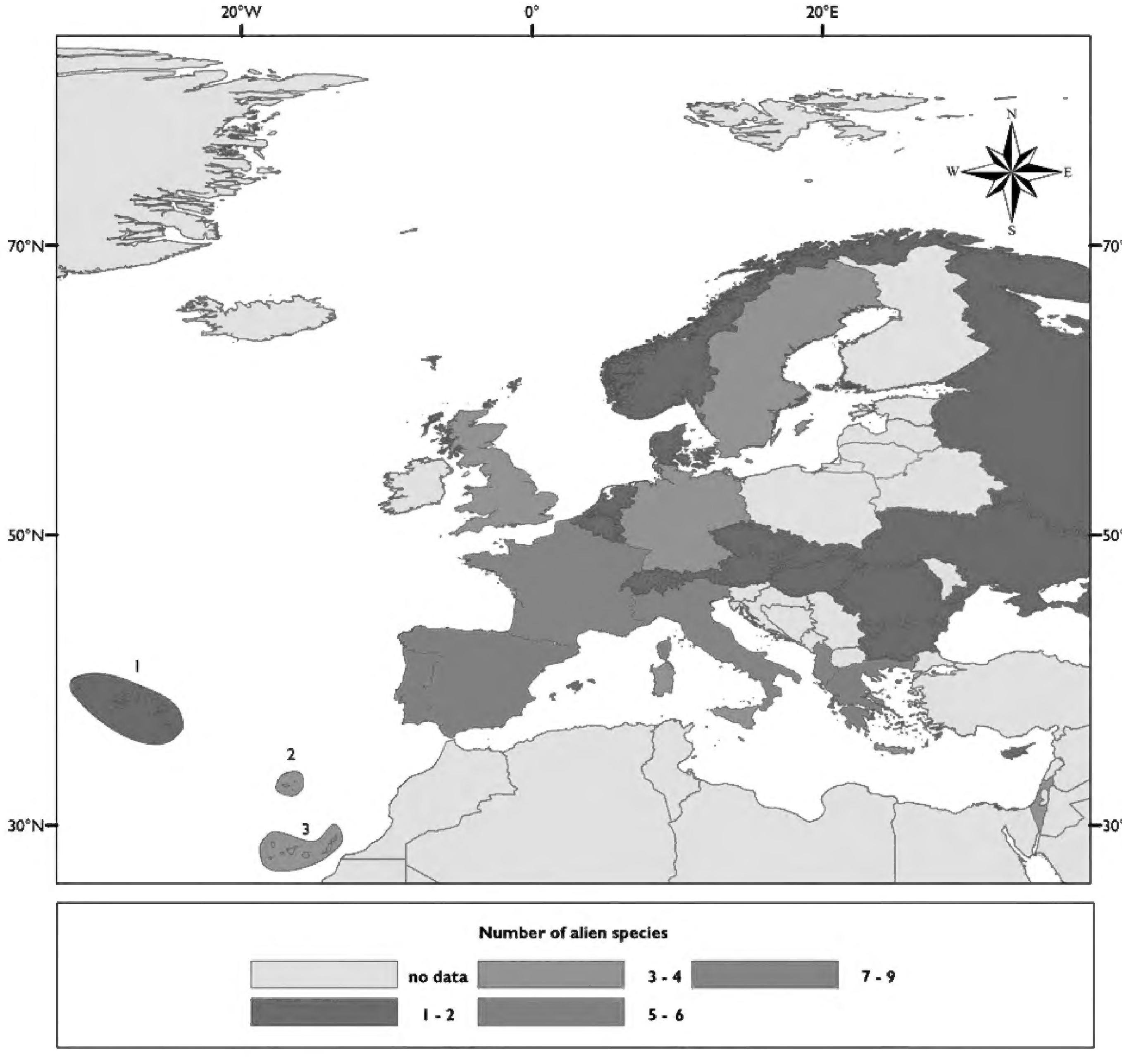

Figure 8.4.3. Colonisation of European countries and islands by coccinellids alien to Europe where known. Scale = total number of recorded alien coccinellids.

(1974), Portugal (1984) and Sweden (2001). This species is considered established in all the countries where it has been released other than Sweden (for which the status of this species is unknown). *Cryptolaemus montrouzieri* has been used extensively through augmentation (release of reared adults) and was the first coccinellid used to demonstrate an inoculative approach (whereby the aim is introduce a small number of individuals into a crop system with the expectation that they will reproduce and their offspring will continue to provide control of the target pest for an extended period of time). *Cryptolaemus montrouzieri* is easy and cheap to culture on mealybugs (Majerus 2004). *Rhyzobius lophanthae* is a species native to New Zealand which was introduced to Italy in 1908 for the control of Diaspididae (armoured scale insects). It has been released widely in European countries including: Portugal (1930 and 1984), Spain (1958), Sardinia (1973), France (1975), Greece (1977) and Germany (2000). This species has recently been reported as established in London, Great Britain (Natural History Museum, 2008).

Figure 8.4.4. Harlequin ladybeetle (*Harmonia axyridis*). Credit: Mark Bond

8.4.6.1 Control of Scale Insects

A number of coccinellid species have been used in historically significant and successful projects for the biological control of scale (Borges et al. 2006, Erler 2001, Katsoyannos 1997) including *R. cardinalis* and *R. lophanthae*. Other species introduced to Europe for control of scales include *Rhyzobius forestieri*, *Nephus reunioni*, *Chilocorus nigritus* and *Chilocorus kuwanae*.

Rhyzobius forestieri (native to Australia) has established in Italy, France, Greece and Albania. In the Cambos coastal plain of Greece this species is now considered the most abundant species of coccinellid within the coccidophagous guild (Katsoyannos 1997). *Nephus reunioni* (native to Africa) was intentionally released in a number of countries (Italy, Portugal, France, Greece, Albania and Spain) and is now considered to be established in Italy and Portugal. *Chilocorus nigritus* is native to the Indian sub-continent and South East Asia and is a candidate biological control agent for the control of species within the Coccoidea including three economically important families (Diaspididae, Pseudococcidae and Coccidae). It has a recent history, 1985 onwards, of introduction to a number of countries: Italy, Denmark, France, Germany, Netherlands, Great Britain and Albania. *Chilocorus kuwanae* is a biological control agent of scale insects and was introduced to Europe (Albania and Italy) from Asia in 1989.

8.4.6.2 Control of Aleyrodidae

The family Aleyrodidae comprises the commonly referred to whiteflies. Over fifty species of coccinellidae attack eggs and immature stages of whitefly pests (Obrycki and Kring 1998, Yigit et al. 2003). There is interesting variation in the preda-

Figure 8.4.5. Adults of *Cynegetis impunctata*. Credit: Gilles San Martin

tory behaviour of these polyphagous coccinellids; some are mobile, seeking out prey, and others are sedentary, and complete preimaginal development on one leaf (Obrycki and Kring 1998). In Europe one species, *Serangium parcesetosum*, has been introduced for the control of whitefly (*Bemisia tabaci*). *Serangium parcesetosum* was introduced from its native range of Asia and the Indian subcontinent to France including Corsica (Majka and McCorquodale 2006). A further species *Delphastus catalinae*, native to North America, has been introduced in glasshouses within Albania and Russia for the control of *Bemisia tabaci* and *Trialeurodes vaporariorum* (Kutuk and Yigit 2007, Legaspi et al. 2008). However, this species has not established in the wild. Studies on the thermal biology of *D. catalinae,* assessing the effects of temperature on development, voltinism and survival in the laboratory and field (non-indigenous range), indicate a strong correlation between survival in the laboratory at 5 °C and in the field in winter (Simmons and Legaspi 2004, Simmons and Legaspi 2007). *Delphastus catalinae* died out quickly in winter temperatures and this suggests that the probability of establishment is low in regions that experience low temperatures and scarcity of suitable food for part of the year (van Lenterenet et al. 2003). In the absence of studies on cold tolerance it is insufficient to assume that, on the basis of climate matching, winter would be an effective barrier to establishment of species originating from warmer climatic zones (van Lenteren et al. 2006). Risk assessments should also be sufficiently detailed to encompass strain specific parameters; the release of a non-diapausing strain versus a diapausing strain could result in very different impacts (van Lenteren et al. 2006). Furthermore, impacts through consumption of non-target hosts and dispersal require considerable attention (van Lenterenet et al. 2003). So, for example, although *D. catalinae* is not anticipated to survive winter temperatures in northern Europe, it is oligophagous

Figure 8.4.6. Adult of the phytophagous bryony ladybeetle, *Henosepilachna argus*. Credit: Mike Majerus.

and reported as an intra-guild predator of the aphelinid parasitoid *Encarsia sophia* (Zang and Liu 2007).

8.4.6.3 Control of Aphids

Hippodamia convergens and *H. axyridis* have both been released extensively throughout Europe for the control of aphids. *Hippodamia convergens* is native to America and several billion are collected annually from overwintering sites in California and sold throughout America. This practice has been shown to be highly ineffective because of adult dispersal (Dixon 2000, Roy and Majerus, unpubl.). Furthermore, removal of *H. convergens* is considered to have adverse effects on local populations and, in America, is responsible for the distribution of two ladybird parasites (the braconid wasp, *Dinocampus coccinellae* and the microsporidian, *Nosema hippodamiae*) (Saito and Bjornson 2006) and vectoring of plant pathogens (dogwood anthracnose fungus) (Bjornson 2008). This coccinellid has been released in Belgium, Sweden, Denmark, Albania and the Czech Republic in the 1990s and early 2000. It is unknown whether or not it is established.

The use of *H. axyridis* as an augmentative biological control agent (mass reared and released) has been widespread (Berkvens et al. 2008, Brown et al. 2008a). In 1982 it was introduced into France and has since been reared continuously over 100 generations on industrially produced eggs of the moth, *Ephestia kuehniella* (Brown et al. 2008a). It has since been introduced to a number of countries across Europe and also spread to others which had not intentionally released it (Table 8.4.3).

Figure 8.4.7. Larva of *Henosepilachna argus*. Credit: Gilles San Martin

8.4.7 Ecosystems and habitats invaded in Europe by alien Coccinellids

Coccinellid species can be classified as stenotopic or eurytopic (Hodek 1993, Iperti 1991). Microclimate is considered to be a particularly important feature of a coccinellid habitat. Many species of ladybird exhibit a preference for specific vegetation types or certain strata of the habitat. Coupled with this is the requirement for suitable food in sufficient abundance. Habitat preference varies seasonally as the microclimatic characteristics of a habitat change, which in turn influences the distribution of prey populations and the behaviour of coccinellids. Iperti (1999) documents the succession of aphid outbreaks in south eastern France; during a normal year aphids first appear on low plants and shrubs, they then progress to cultivated low plants and early deciduous trees and develop on cultivated trees and shrubs. However, climatic conditions vary annually and so it is difficult to predict the behaviour of coccinellids, particularly in a period of climate change.

There is a strong trend for alien coccinellids to occur in urban or cultivated habitats in Europe. Almost all species are most prevalent in recently cultivated agricultural, horticultural and domestic habitats, gardens and parks and greenhouses (EUNIS categories I I1, I2, J100; see appendix II). *Harmonia axyridis,* the most invasive of the alien coccinellids in Europe, follows this pattern although there have been a considerable number of records in Great Britain from natural habitats (Brown et al. 2008b). Indeed, *H. axyridis* is documented from both woodlands and forest habitats, small anthropogenic woodlands, parks and gardens, agricultural and horticultural habitats as well as from buildings in cities, towns and villages.

The abundance of native and alien coccinellid species in urban habitats and their tendency to aggregate in large numbers during autumn and winter enhances their

visibility to people. This aggregation behaviour can be exploited by biological control practitioners through the collection and release of large numbers of beetles but species that exhibit this behaviour, such as *H. axyridis*, are increasingly seen as nuisance insects in domestic dwellings (Roy and Majerus 2006, Roy et al. 2008).

8.4.8 Ecological and economic impacts of alien coccinellids

The ecological and economic impacts of alien coccinellids are not well documented. Many authors have noted the low success rate of coccinellids as biological control agents of aphids (Dixon 2000, Iperti 1999, Majerus et al. 2006a). The success of coccinellids as biological control agents of coccids is higher than that of aphids but still relatively low at only 40 % of cases studied being designated as exerting complete or substantial control (Iperti 1999).

Rodolia cardinalis has been heralded as a success story for biological control (Caltagirone 1989). This species has been introduced into 33 countries to control *I. purchasi* and has yielded complete control in 26 countries (North America, Argentina, Peru, Chile, Portugal, Uruguay, Venezuela, France, Italy, Spain, Greece, Morocco, Tunisia, Turkey, Egypt, India, Japan and New Zealand); substantial control in four countries (Russia, Libya, the Bahamas, Ecuador) and partial control in two countries (Seychelles and Mauritius). A similar rate of success was achieved through the acclimatization of *C. montrouzieri* to control *Pseudococcus* spp. (Iperti 1999). Therefore, *R. cardinalis* and *C. montrouzieri* have contributed economic benefits through the ecosystem service they provide. Indeed, the initial cost of the *R. cardinalis* introduction programme in California 1888 was $1 500 with a return in just over a year of millions of dollars (Majerus 2004).

The lack of success of aphidophagous coccinellids has been attributed to asynchrony between the reproductive and development rates of the predatory coccinellids and their aphid prey (Dixon 2000). Furthermore, many aphidophagous coccinellids, in temperate climates, are univoltine whereas aphids are multivoltine. Coccidophagous coccinellids tend to stay in a localised area throughout their life cycle and, in contrast, aphidophagous coccinellids disperse widely (Iperti 1999).

Most intentional insect introductions do not cause ecological or economic problems, indeed of all the intentionally introduced insects to North America only 1.4 % have caused problems (van Lenteren et al. 2003). Indeed insect introductions are considered to be relatively safe: less than 1 % cause a population level effect in non-targets and only 3–5 % may have caused smaller scale effects (van Lenterenet et al. 2003). However, a number of coccinellids are documented as having non-target effects (van Lenterenet et al. 2003). *Cryptolaemus montrouzieri* is reported to lower the effectiveness of an introduced natural enemy (*Dactylopius opuntiae*) for weed control (Goeden and Louda 1976). The most infamous coccinellid introduction is undoubtedly *H. axyridis* (Majerus et al. 2006b, Roy and Majerus 2006, Roy et al. 2005, Roy and Wajnberg 2008).

Harmonia axyridis has been released as a classical biological control agent in North America since 1916. It has been commercially available in Europe since the 1980s and has many attributes that contribute to its economic viability, including its polyphagous nature. *Harmonia axyridis* preys on a wide variety of tree-dwelling homopteran insects, such as aphids, psyllids, coccids, adelgids and other insects (Koch et al. 2006). In North America, as well as offering effective control of target pests, such as aphids in pecans (Tedders and Schaefer 1994), *H. axyridis* is also providing control of pests in other systems such as *Aphis spiraecola* in apple orchards (Brown and Miller 1998) and several citrus pests (Michaud 2002). In both Asia and North America, *H. axyridis* has been reported to contribute to control of aphids on sweet corn, alfalfa, cotton, tobacco, winter wheat and soybean (Longo et al. 1994). The spread and increase of *H. axyridis* throughout Europe could, therefore, prove to be beneficial to ecosystem services through the reduction in aphid numbers below economically damaging levels and subsequent reduction in the use of chemical pesticides.

The polyphagous nature of *H. axyridis* means that negative impacts on non-target prey species would appear to be inevitable (Majerus 2006, Pell et al. 2008). However, there is very limited empirical evidence on this subject and studies considering the effects of *H. axyridis* on the population demography of non-target aphids, coccids and other prey species away from crop systems have not been conducted. *Harmonia axyridis* has been implicated as a potential predator of immature monarch butterflies, *Danaus plexippus*, an aposematic species that contains defensive chemicals (Koch et al. 2003). Laboratory studies have also indicated the potential for *H. axyridis* to engage in intra-guild predation (Pell et al. 2008, Roy et al. 2008, Ware and Majerus 2008). It is likely that many other species will be directly or indirectly affected by the arrival of *H. axyridis*. Indeed, intraguild predation is thought to be an important force in structuring aphidophagous ladybird guilds (Yasuda et al. 2004) and so *H. axyridis* has the potential to dramatically disrupt native guilds in Europe. *Harmonia axyridis* is a large, aggressive, polyphagous coccinellid (with a tendency for intraguild predation) that could impact on the abundance of native coccinellids and reduce their available niches (Legaspi et al. 2008).

The wide dietary range of *H. axyridis* coupled with its ability to disperse rapidly, forage widely and continuously breed gives this species the potential to significantly reduce European populations of coccids and aphids. This is, of course, considered beneficial in crop and horticultural systems, but not in other habitats where such direct competition for prey may result in a reduction in biodiversity and declines in native beneficial predators and parasitoids of aphids and coccids (Majerus 2006).

Majerus et al. (2008) noted that the negative effects of *H. axyridis* on other aphidophages are likely to be the result of a complex range of interactions, with *H. axyridis* in general having a competitive edge through resource competition, intraguild predation and a more plastic phenotype. A more rapid development rate, continual breeding ability and lack of diapause requirement, efficient chemical defence and relatively large size would provide *H. axyridis* with a significant reproductive advantage over many native British species. The pattern is anticipated to be widespread throughout Europe (Brown et al. 2008a).

8.4.10 Conclusions

Coccinellids have been introduced widely throughout Europe for the biological control of pest insects. Some of these species have established and for others the status is unknown. It is difficult to estimate the proportion of alien coccinellids in Europe for two reasons: there is not a definitive European check list for coccinellids and the status of some of the alien species is unknown. However, the proportion of alien coccinellids appears to be higher (approximately 5–10 %) than the proportion of aliens for other taxonomic groups (3.1 % alien Diptera). Only one species (*H. axyridis*) is considered to be invasive.

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Table 8.4.1. List and main characteristics of the Coccinellidae species alien to Europe. Status: **A** Alien to Europe **C** cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Phylogeny after (2 0, 35). Last update 01/03/2010.

Subfamily *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Coccidulinae								
Rhyzobius forestieri (Mulsant, 1853)	A	Parasitic/ Predator	Australasia	1982, IT	AL, FR, GR, IT	I	Coccids (Scale insects)	Katsoyannos (1997)
Rhyzobius lophanthae (Blaisdell, 1892)	A	Parasitic/ Predator	Australasia	1908, IT	AL, DE, ES, ES-BAL, FR, FR-COR, GB, GR,GR-CRE, IT, IT-SAR, IT-SIC, IL, MT, PT, PT-AZO, PT-MAD,	I, J100	Coccids (Scale insects specifically Diaspididae)	Erler (2001)
Rodolia cardinalis (Mulsant, 1850)	A	Parasitic/ Predator	Australasia	1888, PT	AL, CH, CY, DE, ES, ES-BAL, ES-CAN, FR, FR-COR, GB, GR, GR-CRE, IL, IT, IT-SAR, IT-SIC, MT, PT, PT-AZO, PT-MAD, UA	I, J100	Coccids (Scale insects)	Caltagirone (1989), Frank and McCoy (2007)
Scymninae								
Hyperaspis pantherina Fürsch, 1975	A	Parasitic/ Predator	Africa	2002, PT-MAD	PT-MAD	U	*Orthezia insignis* (Scale insect)	Booth et al. (1995), Fowler (2004)
Cryptolaemus montrouzieri Mulsant, 1853	A	Parasitic/ Predator	Australasia	1908, IT	AL, ES, ES-CAN, FR, FR-COR, GR,GR-CRE, IL, IT, IT-SAR, IT-SIC, PT, RU, SE,	I, J100	Mealybugs	Hamid and Michelakis (1994), Smith and Krischik (2000)
Nephus reunioni Fürsch, 1974	A	Parasitic/ Predator	Africa	1983, FR	AL, ES, FR, GR, IT-SAR, PT	I	Coccids (Scale insects)	Izhevsky and Orlinsky (1988)
Chilocorinae								
Chilocorus kuwanae Silvestri, 1909	A	Parasitic/ Predator	Asia	1989, IT	AL, IT	I	Coccids (Scale insects)	Ponsonby and Copland (2007b), Ricci et al. (2006)
Chilocorus nigritus (Fabricius, 1798)	A	Parasitic/ Predator	Asia	1994, IT	AL, ,IT	I, J100	Coccids (Scale insects)	Booth (1998), Ponsonby and Copland (2007a), Ponsonby and Copland (2007b)

Subfamily *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Sticholotidinae								
Serangium parcesetosum Sicard, 1929	A	Parasitic/ Predator	Asia	1986, FR-COR	FR, FR-COR	I	Aleyrodidae	Yigit and Canhilal (2005), Yigit et al. (2003)
Coccinellinae								
Harmonia axyridis (Pallas, 1773)	A	Parasitic/ Predator	Asia	1991, BE	AL, AT, BE, BG, BY, CH, CZ, DE, DK, ES, ES-CAN, FR, FR-COR, GB, GR, GR-CRE, GR-ION, GR-SEG, HU, IL, IT, IT-SIC, , LI, LU, NL, NO, PT, RO, RU, SE, SK, UA	I	Polyphagous insect predator particularly aphids and coccids	Adriaens et al. (2003), Adriaens et al. (2008), Brown et al. (2008a), Brown et al. (2008b), Koch et al. (2003), Majerus (1994), Roy et al. (2005), Roy and Wajnberg (2008)
Hippodamia convergens Guerin-Meneville, 1842	A	Parasitic/ Predator	North America	1992, CZ	AL, BE, CZ, DK, SE	FA, J100	Aphids	Bjornson (2008), Phoofolo et al. (2008), Saito and Bjornson (2006)

Table 8.4.2. List and main characteristics of the Coccinellidae species alien within Europe. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Phylogeny after Fürsch (1990), Koch et al. (2006). Last update 01/03/2010.

SubFamily *Species*	Regime	Native range	Invaded countries	Habitat*	Hosts	References
Scymninae						
Scymnus impexus Mulsant, 1850*	Parasitic/ Predator	West Palearctic	GB, SE	G, I2	*Dreyfusia piceae* on spruce and fir	Humble (1994), Majka and McCorquodale (2006)
Epilachninae						
Henosepilachna argus (Geoffroy, 1762)*	Phyto-phagous	West Palearctic	GB	E5, I2, FA	White bryony (*Bryonia dioica*)	Hill et al. (2005)

Table 8.4.3. Summary of release dates and records from wild populations of *Harmonia axyridis* across Europe. Adapted from Brown et al. (2008a). Updated: 01/03/2010

Country	Year of release (blank if not released)	Year of first record in the wild
Ukraine	1964	Unknown
Belarus	1968	Unknown
Portugal	1984	
France	1982	1991
Greece	1994	1998
Germany	1997	1999
Belgium	1997	2001
Netherlands	1996	2002
Spain	1995	2003
Switzerland	1996	2004
Luxembourg		2004
England and Channel Isl.		2004
Italy	1990s	2006
Czech Republic	2003	2006
Austria		2006
Denmark	2000s	2006
Wales		2006
Norway		2006
Poland		2007
Liechtenstein		2007
Sweden		2007
Northern Ireland		2007
Scotland		2007
Serbia		2008
Slovakia		2008
Hungary		2008
Bulgaria		2009
Romania		2009